114th Meeting of the LHC Collimation Study Group

April 12, 2010

Present: R. Assmann (chairman), A. Nordt (acting for scientific secretary A. Rossi), D. Wollmann, R. Bruce, L. Keller (SLAC), J. Jowett, A. Bertarelli, J. Smith (SLAC), J.-Ph. Tock
Excused: O. Aberle Comments to the minutes
No comments to the previous minutes.

1 Agenda of this meeting

1. Regular collimation status reports:
    a) Hardware and tunnel activities, if any
    b) Remote and beam commissioning
    c) Phase II activities at CERN
    d) Phase II activities at SLAC
    e) Cryo-collimators
    f) FLUKA work

2. Special reports :
    a) Comparison of carbon and Hi-Z primary collimators for Phase 2 – L. Keller, SLAC
    b) Layout studies for IR3 cryo-collimators – J. Jowett, BE/ABP

2 List of actions from this meeting

Action	People	Deadline
Dedicated simulations of scenarios run in 2009 to compare with measurements.	FLUKA team	
Provide details on the type of steel used for the tank.	SLAC	
Present at the CWG materials being studied for Phase II collimation.	E. Metral	
Establish if octupoles are needed at 3.5 TeV.	E. Metral	
Check heating power on collimator at nominal LHC operations.	E. Metral	
Estimates of residual dose in IR3 for different shut-downs.	S. Roesler	

(Complete list at http://lhc-collimation.web.cern.ch/lhc-collimation/action.htm)

The next meeting will be on April 26th.

Minutes of the meeting

1 Regular collimation status reports

1.1 Hardware and tunnel activities (O. Aberle EN/STI)

- No hardware problem reported.
- Tests foreseen for week 15 and 16 of 2010.

1.2 Remote and beam commissioning (R.W. Assmann BE/ABP)

- Remote commissioning worked fine.

1.3 Phase II activities at CERN (A. Dallocchio, EN/MME)

- Analyze 2 alternative designs for cryo-collimators (warm and superconductive collimators).
- Both designs are single jaw designs.
- Need FLUKA simulations for backward scattering.
- Impact on first jaw, but where do the 30% of the other jaw go to?
- It is difficult to design it in case an additional jaw is required.
- Results are expected within the next 3 month.
- First phase II collimators are ready in the middle of 2010.

1.4 Phase II activities at SLAC (J.C. Smith)

- The construction of the vacuum chamber has been finished.
- The rotation mechanism appears to work well.
- Concerning the jaw rotation there was the question: which side to use?
- It would be better to use a retch on the inner side.
- There seems to be an off-axis problem for the positioning of the jaw after the rotation.
- The August delivery can be met.
- The drawing folders will be sent to Alessandro Bertarelli.

1.5 Cryo-collimators

- A discussion is foreseen with the MME designers to find as short length as possible solution for the cryo-collimators (IP3 and IP7).

1.6 FLUKA

- A talk is foreseen next week on results of losses at 3.5TeV on warm and cold regions.

2 Special topics

2.1 Comparison of carbon and Hi-Z primary collimators for Phase 2 (L. Keller, J. Smith – SLAC and Th. Weiler – Universität Karlsruhe) – see slides

- The motivation of this study is to reduce the number of single-diffractive protons lost in the dispersion suppressor regions and to reduce the energy deposition in warm magnets and beam pipes near the primary collimators.
- The choice of tungsten as a material for the primary collimators has several reasons:
    1. Reduction of halo losses from nuclear interactions (and in particular single-diffractive scattering) as well as increase the halo losses from multiple Coulomb scattering (MCS).

2. MCS scales with 1/√ radiation length for a given thickness of the material and the goal is to minimize the ratio ® of radiation length to nuclear interaction length, i.e. the opposite of the Phase I philosophy.
3. For C-C: R~24cm/48cm=0.5 and for W: R=0.35cm/9.6cm=0.036.
4. Tungsten probably does not need water cooling and will not be damaged as long as t<3-4 RL.

- A plot showing the probability of various interactions per incident proton was presented: On momentum protons which scatter more than 8 μrad in the horizontal plane hit the secondary collimators; otherwise they go around the ring again. Based on the large ratio of MCS > 8 μrad to single-diff and the desire to keep number of nuclear interactions as small as possible, choose 1.5 r.l. (0.525 cm) tungsten.
- Conditions for SixTrack runs:
  1. 7 TeV, V6_500 optics, low beta, beam 1, sextuples on, 'perfect' machine.
  2. Halo on TCPH, jaws parallel, 4e11 loss rate unless otherwise specified.
  3. Halo dE/E=0.
  4. Collimator settings: primaries at 6 sigma (carbon or tungsten); secondaries at 7 sigma (copper); absorbers at 10 sigma (tungsten); tertiaries at 8.3 sigma (tungsten).
  5. Additional: a) trajectories of all single diffractive protons just down from TCPH.
     b) trajectories of all single-diffractive protons which reach the beginning of the DS.
- The proton loss rate distribution in the DS was presented for single diffractive trajectories from TCPH (ratio carbon/tungsten=3.0) and loss rate including re-scattering from the TCSM's (ratio carbon/tungsten=2.2).
- The local and global inefficiency has been presented: the global inefficiency is about a factor 2 worse for W at 10 sigma.
- The SixTrack fractional distribution of inelastic impacts on Phase II collimators and the steady state power distribution on IR7 magnets and on Phase II collimators and absorbers have been presented.
- Summary of energy loss in IR7 with 0.5cm W primary collimators:
  1. The predominant halo loss occurs from multiple Coulomb scattering in the primary collimators causing inelastic impacts in the secondary collimator system.
  2. There are approximately a factor of 3 fewer inelastic impacts on the primary collimators resulting in a corresponding factor less radiation dose on the nearby warm magnets and beam pipes and 30% less dose to quads and dipoles. The dose is also spread more uniformly in IR7.
  3. There is a factor of 2.5 less energy loss on the first secondary collimator but 50% more energy is contained in the copper secondary collimators.
- Energy deposition in a 0.5cm tungsten radiator:
  1. Use of tungsten with 25% rhenium: stronger and more ductile (D.Walz).
  2. Steady state (5e10p/sec) heating: 0.4W for each jaw (FLUKA).
  3. Accident (9e11 p in 8 bunches) heating: ΔT~900°C (W-Re melting point is at 3200°C)--> as robust as carbon for accident heating.
  4. For a thin radiator the temperature rise in an accident is proportional to the number of protons, so it must be retracted during the injection.

  Questions:
  - Is water cooling necessary for the steady state running (0.4W/jaw)?
  - Could 3 of these thin radiator assemblies be put into the 2m space reserved for TCP.A6L7 (TCPS2)?

- Summary: Phase II with a tungsten 0.5cm primary collimator (compared to 60cm carbon):
  - SixTrack has shown that cold losses in the DS are 2.2 times smaller.
  - The radiation dose is a factor 3 smaller in nearby warm magnets.
  - Energy deposition in the 1st secondary collimator, TCSM.A6L7 is 2.5 times smaller.
  - Losses on tertiary collimators in IR8, IR1 and IR2 are 2 to 5 times larger (IR3 and IR5 are lower)---more study is needed.
  - The global inefficiency is 1.8 times higher---needs more study.
  - The jaws of a thin W radiator receive a small steady state power and easily survive a full 8-bunch kicker misfire accident.
- Ralph confirms the results, but the robustness needs to be investigated: carbon scrapers are more robust than tungsten (compare the robustness).
- How many protons were used?

- Follow up: robustness comparison for the 2 devices.

2.2 Layout studies for IR3 cryo-collimators (J. Jowett BE/ABP) – see slides

- The baseline layout and new optics for IR7 were given in April 2009.
- Here the layouts for IR3 were presented.
- The baseline layout: minimizes geometrical perturbations and it should be not too difficult to recover similar optics.
- Beam1 in R3: move outer group of elements 3m away from IP to missing dipole space and move inner group of elements 3m towards IP in order to compensate the change in geometry.
- Displacements of reference orbits for B1: longitudinal displacement mainly reflects a change in length of the reference orbit (can be fixed). And the radial displacement of reference orbit between shifted sections is by 30mm. Not the displacements of elements.
- Displacements of moved elements (B1,L7): In the global Cartesian frame, the displacements of the outer and inner groups of elements include a component from the angle ('curvature') of the initial reference orbit.
- MAD and the LHC layout DB use the 'beads on a necklace' method of laying out the machine, so everything downstream of OR7 moves and the ring does not close (not real, correction needed for that).
- The corrected layout includes small negative displacements of all elements downstream of IR7 along the reference orbit and restores them to their original position in the global Cartesian system and closes the ring.
- New sequence descriptions are created for both rings.
- The LHC circumference is changed by -1.872mm.
- The change in layout perturbs the optical functions, giving about 20% β-beating which must be corrected.
- Rematch IR3 for each ring without using the common quadrupoles that effect both (this is done for IR7 but not yet for IR3).
- The alternative layout, avoiding moving DFB is difficult due to lateral space limitations: move outer group of elements 6m away from IP into the missing dipole space and move inner group of elements 3m away from the IP. This is leaving to another space (similarly on R3).
- If zooming on displacements along the reference orbit: it vacates enough space in the right places to install the cryogenic collimators (no change in LHC geometry is seen).
- The longitudinal displacement of the reference orbit (B1) mainly reflects a change in length of the reference orbit (can be fixed). The radial displacement of the reference orbit between the long sections is 120mm (not the displacement of the elements).
- The displacements of moved elements (B1, L7): in the Cartesian frame the displacements of the outer and inner groups of elements include a component from the angle ('curvature') of the initial reference orbit. MAD and the LHC layout DB use the 'beads on a necklace' method of laying out the machine, so everything downstream of IR3 moves and the ring does not close: this is not real but has to be corrected in the current description.
- The corrected layout has small negative displacements of all elements downstream of IR3 along the reference orbit and restores them to their original position in the global Cartesian system and closes the ring. A new sequence description has been created for both rings. The LHC circumference is changed by -6.865mm.
- A change in layout perturbs the optical functions, giving about 20% β-beating which must be corrected. Rematch IR3 for each ring without using the common quadrupoles that affect both looks feasible but is not yet done.
- Conclusions: baseline layout for cryo-collimators in IR3 is similar to IR7 (minimizing geometrical perturbation as expected): it should be possible to match the optics.
- An alternative approach has been proposed by JP Tock: displacing the central straight section by 122.3mm towards the centre of the ring; larger displacements up to 153mm of some other elements and if it is acceptable, the optics should be still checked. Due to the large displacement, this solution is being ruled out.